Fish and Wildlife Research 6

Water and Habitat Dynamics of the Mingo Swamp in Southeastern Missouri

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Water and Habitat Dynamics of the Mingo Swamp in Southeastern Missouri

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Abstract

The present report describes surface water relations in a lowland hardwood wetland in the Upper Mississippi Alluvial Valley (MAV). Water regimes were examined by sampling habitats within the Mingo Basin (hereafter, Mingo Swamp) in southeastern Missouri weekly from February 1981 to May 1983. Habitat changes within the Swamp were documented from 1880 to 1983. Habitats within the Mingo Swamp are distributed along elevational and water regime gradients. Lands below 335 ft mean sea level support primarily baldcypress and open-water habitats immediately surrounded by scrub/shrub habitats. Live forests (naturally flooded and green-tree reservoir) occur at higher elevations (336–344 ft) and composed 54% of all habitats in the Mingo Swamp in 1983, 59% in 1973, 63% in 1966, 67% in 1955, 63% in 1941, and 82% in 1880. Dead-tree habitats increased from <1% of the area before 1973 to about 5% by 1983. The live forest is dominated by even-aged stands (mostly 30–40 years old) of pin oaks (*Quercus palustris*). Light gaps compose about 3% of the forest area. Scrub/shrub, open marsh, and newly created dead-tree habitats usually contained some water >80% of the year and >65% of the growing season. Overcup oak (*Quercus lyrata*) habitats contained some surface water from November to April each year. Pin oak habitats were usually partly flooded from December to May but were seldom 100% flooded and rarely had surface water >20 cm deep.

Light penetration of all waters was low and decreased with increased rainfall and flooding. Alkalinity and conductivity were lower than in most other North American wetlands. pH decreased in fall and winter.

Waters flood lowland hardwood wetlands in three ways: on-site rainfall and puddling, backwater flooding, and headwater flooding. Shifts in drainage flow and redistribution of sediments (drainage dynamics) together with tree falls maintain the interspersed and diverse lowland hardwood ecosystem. Lowland hardwood forests within the Upper MAV contain mostly pin oak habitats and are flooded more shallowly, and more by on-site rainfall, than in Lower MAV regions.

Management suggestions include emulation of natural water regimes; restriction of road, levee, and borrow area construction; control of beaver populations; and continued protection of existing lowland hardwood forests in the Upper MAV.

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Lowland hardwood wetlands occupy the broad floodplains of the Mississippi Alluvial Valley (MAV), and once encompassed >10 million ha. At present less than 2 million ha of lowland hardwood wetlands remain, with less than 0.7 million ha retaining original ecological functions (Fredrickson 1979a; MacDonald et al. 1979). Loss of forested wetlands has occurred 5 times faster than loss of nonwetland forests in the last 40 years (Abernethy and Turner 1987). The loss of forested wetlands, together with their economic and ecological importance to water regimes, nutrient cycles, and plant and animal communities, has generated increased efforts in recent years to preserve and manage these habitats. For example, the U.S. Fish and Wildlife Service (FWS) recently designated lowland hardwood wetlands in the MAV as the number three priority for acquisition and protection of waterfowl habitat in the United States. Additionally, the North American Waterfowl Management Plan calls for protection of 277,800 ha of habitat, much of which is lowland hardwood, in the lower Mississippi River-Gulf Coast region (Canadian Wildlife Service and U.S. Fish and Wildlife Service 1986).

Management of existing lowland hardwoods by private and public agencies has increased since the 1940's. Most managed lands are manipulated for wildlife, forest, or recreational purposes. Most management activities, especially those manipulating water regimes, have immediate demonstrable effects on the surrounding wetland environment but may also have subtle, often more profound, influences. The effects of some of these management activities are partly known (Fredrickson 1979b, 1980; Cairns et al. 1981); other subtle or long-term effects are unknown or poorly understood.

Understanding water regimes is essential to interpreting the structure and function of lowland hardwood wetlands and for evaluating and setting priorities for acquisition and management. The timing, depth, duration, and extent of flooding influences the distribution, composition, and productivity of vegetation (Bedinger 1971, 1979), groundwater recharge (Carter et al. 1979), water quality (Carter et al. 1979; Wharton et al. 1982), and nutrient and energy flow (Livingston and Loucks 1979; Mitsch et al. 1979). These water relations have been extensively studied in middle and lower regions of the MAV (Brown 1943; Newcome and Page 1962; Bedinger 1971, 1979; McKnight et al. 1981), but few studies have addressed hydrological aspects of the Upper MAV (northeastern Arkansas, southeastern Missouri, southern Illinois, and western Tennessee).

We describe lowland hardwood distribution and water relations in the Mingo Basin (hereafter, Mingo Swamp) in southeastern Missouri in 1981–83. These relations are examined in light of past and present management activities within the Mingo Swamp and to provide a historical perspective on lowland hardwood wetland communities in the Upper MAV.

Study Area

The present study was conducted on the floodable lands (i.e., lands with a documented history of water coverage at the highest flood mark, 344 ft elevation) of the Mingo National Wildlife Refuge (MNWR) and the Duck Creek Wildlife Management Area (DCWMA) in the Mingo Swamp of southeastern Missouri (Fig. 1). The Mingo Swamp lies within the Advance Lowlands, an abandoned channel and floodplain of the Mississippi River (Marbut 1902; Saucier 1968, 1970). The Advance Lowlands are bounded on the north and west by the Ozark Escarpment and on the south and east by Crowley's Ridge. The St. Francis River flows from the Ozark Hills into the Advance Lowlands just south and west of the Mingo Swamp. When the Mississippi River vacated the Advance Lowlands (ca. 18,000 B.P.), an alluvial fan built up where the St. Francis River entered the lowlands. The Castor River, north and east of the Mingo Swamp, developed a similar alluvial fan. The formation of these alluvial fans on the flat floor of the lowlands between the uplifts along Crowley's Ridge and the Ozark Escarpment created a basin with poor drainage, which is the present Mingo Swamp.

The floodable lands of the Mingo Swamp encompass about 9,312 ha. Soils of the Mingo Swamp are of the Calhoun series developed on alluvium, capped by silty Waverly and Falaya loams deposited during backwater flooding into the basin. A hardpan is present at about 50 cm. Two areas of very low elevation (Monopoly and Rockhouse marshes) have dark organic soils formed under wet, marshy conditions. Scattered sand ridges occur on higher terraces. Soil pH ranges from 4.3 to 5.0 and soils are generally low in calcium, magnesium, and potassium (Fredrickson 1979c).

Primary wetland habitat classification types (Cowardin et al. 1979) within the Mingo Swamp are as follows:

Palustrine
- forested wetland
  - broad-leaved deciduous (hereafter referred to as live forest)
  - needle-leaved deciduous (hereafter, open bald-cypress)
  - dead (hereafter, dead tree)

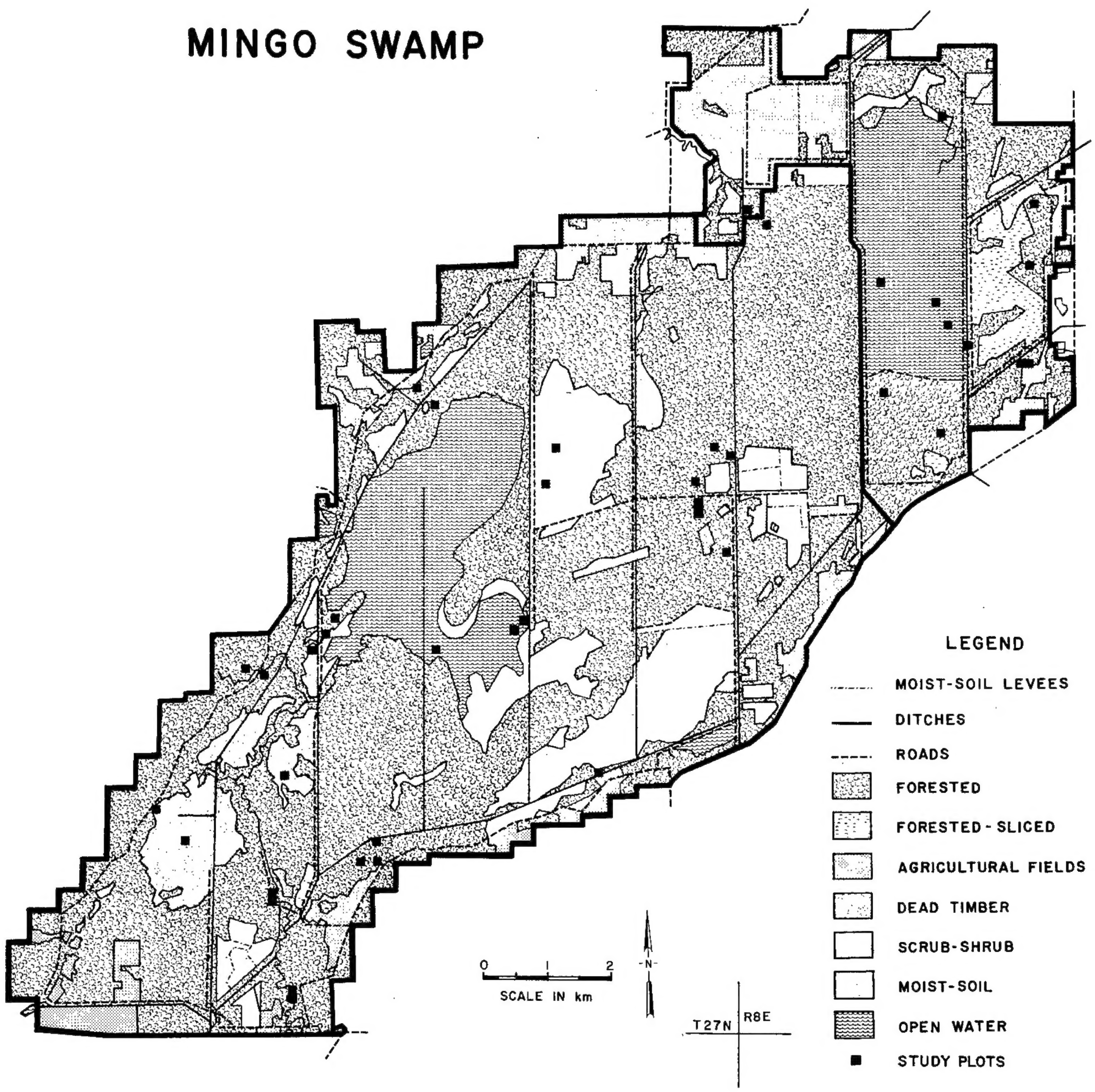


Fig. 1. Map of the Mingo Swamp in 1983 showing habitat types and study plot locations.

broad-leaved deciduous—impounded (hereafter, green-tree reservoir or GTR)

scrub/shrub

broad-leaved deciduous (hereafter, scrub/shrub or S/S)

emergent wetland

persistent and nonpersistent (hereafter, open marsh)

aquatic bed

floating or rooted vascular (some are impounded; wetlands in this classification include open water, ditches, and sloughs with abundant aquatic vegetation)

Palustrine or Lacustrine

unconsolidated bottom

mud (some are impounded; hereafter, open water)

Riverine (hereafter, rivers and creeks)

Fifteen ditches were dug in the early 1920's in an attempt to drain the Mingo Swamp. The topography of the basin in conjunction with floods and subsurface water characteristics precluded drainage efforts, and attempts to clear forests and farm the basin were largely unsuccessful. After most of the Mingo Swamp was purchased by the FWS in 1945, a water control structure was placed on the main outlet for the 15 ditches. Earthen

plugs were used to manipulate water levels in Monopoly and Rockhouse marshes, which have been reciprocally flooded or drained in summer since 1970. More sophisticated water control structures were constructed in 1980 to give more precise control for regulating water levels in these two marshes.

Methods

Area and Distribution of Habitats

The areas (hectares) and elevations (feet above mean sea level, MSL) of major habitat types present in the Mingo Swamp were determined by planimetering aerial photographs taken in 1941, 1955, 1966, 1973, and 1983 and from U.S. Geological Survey topographic maps. All habitats identified on the 1983 photos were groundtruthed. All habitats identified from earlier photos were confirmed by MNWR records and personnel and by long-term area residents. Some errors in identifying habitats from early photos may have occurred, but the major habitat types that we used are usually easily distinguishable from aerial photos (e.g., live forest vs. open water).

Areas in roads, ditches, and manmade ponds were estimated by expanding borrow area, road surface, and levee widths (obtained from engineering specifications when built; U.S. Fish and Wildlife Service and Missouri Department of Conservation) to the total lengths of roads and levees within the Mingo Swamp. The areas of rivers and ditches were estimated by multiplying widths (determined from ground reconnaissance) by total lengths (measured from aerial photos).

The area and distribution of habitat types present within the Mingo Swamp immediately before human intervention in the 1880's (Ogilvie 1967) was estimated. These estimates were made by extrapolating habitat areas present in 1941 backwards to 1880 on the basis of data obtained in this and other studies on the habitats that normally occur at specific elevations and water regimes; percentages of sloughs, rivers, and natural ponds within live forests; MNWR records; conversations with local residents; geological history (Saucier 1968, 1970); and historical accounts of similar habitats within the Upper MAV (Widmann 1895, 1907; Forrister 1970).

Sampling of Habitats

A stratified random sample of 2.02-ha plots distributed proportionately to the area of six habitat types (live forest, open water, S/S, dead tree, GTR, and ditches and creeks) identified from aerial photographs was used to describe water regimes (Fig. 1). Intersections of section lines in the Mingo Swamp were numbered and two-stage cluster sampling was used to select cluster centers, where two plots were randomly drawn from the 0.5-square-mile quadrants surrounding the center. Therefore all 2.02-ha plots within the sampled area theoretically had an equal chance of being selected.

We drew 42 plots for sampling. The habitat area on all plots was mapped and was composed of the following percentages of the six habitat types: live forest = 51.45% (0.97% of total live forest in the Mingo Swamp), open marsh = 13.21% (0.99% of total marsh area), S/S = 10.62% (1.64% of total S/S area), dead tree = 7.5% (1.39% of total dead-tree area), GTR = 9.71% (1.56% of total GTR area), and rivers and ditches = 4.05% (3.42% of total river and ditch area).

Subdivision of Major Habitat Types

The 6 major habitat types sampled were subdivided into 14 habitat types based on tree and shrub species composition and water management to describe the lowland hardwood continuum in greater detail (Fig. 2). The boundaries and areas of subhabitats on each plot were mapped according to vegetation present. Vegetation and physical characteristics used to define subhabitats are as follows:

1. Dead tree–new (DN): recently killed (<10 years, as determined from aerial photos) areas of forest. Baldcypress (*Taxodium distichum*) trees are scattered throughout the standing dead trees. The understory is dominated by buttonbush (*Cephalanthus occidentalis*) and *Bidens*. Dense mats of algae (primarily Chlorophyta), duckweed-like plants (i.e., *Lemna*, *Spirodela*, *Wolffia*, *Azolla*), and floating or submergent plants (*Utricularia*, *Myriophyllum*, *Ceratophyllum*) occur in standing water.
2. Dead tree–old (DO): areas of forest dead >10 years. These areas usually had <50% of tree trunks left standing. Vegetation is similar to DN habitats but with more buttonbush and less *Bidens*.
3. Ditches (D): the 15 ditches cut through Mingo Swamp in the early 1920's. These ditches are about 12 m wide and are mostly <2 m deep. Ditches often have buttonbush along edges and dense mats of duckweeds cover the water surface of most ditches from June through October.
4. Rivers (R): the natural drainages in and out of the swamp. Baldcypress and water tupelo (*Nyssa aquatica*)

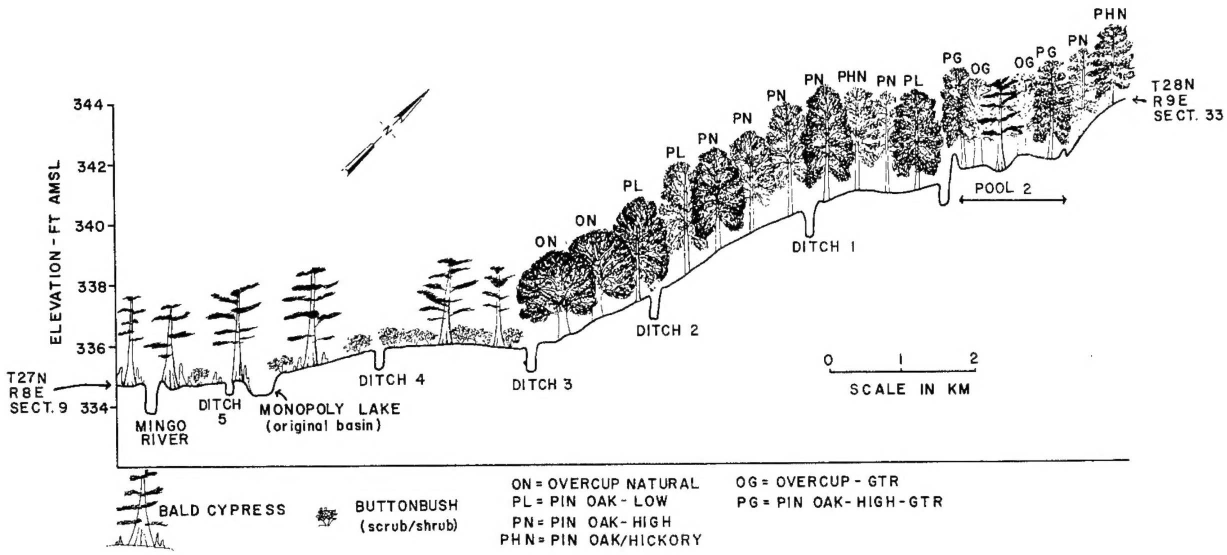


Fig. 2. Cross-section of the Mingo Swamp showing distribution of habitats in relation to elevation and water management.

occasionally grow within the channels, especially where waterflow is sluggish. The original flow of most tributaries is reduced because of water control structures. Floating and submergent vegetation includes duckweeds, *Myriophyllum*, and *Ceratophyllum*.

5. Open marsh (OM): Monopoly and Rockhouse marshes and seasonally flooded impoundments. Baldcypress trees are interspersed with scattered buttonbush in lower elevations. Emergent vegetation is dominated by Poaceae, Nymphacae, Polygonaceae, Cyperaceae, Juncaceae, and Asteraceae, depending on water management (Fredrickson and Taylor 1982).

6. Open water (OW): farm ponds and Pool 1 on DCWMA. OW habitats historically included natural ponds and sloughs. Most OW habitats have baldcypress scattered throughout and have dense submergent mats of *Myriophyllum*, *Ceratophyllum*, and *Utricularia*, and floating or emergent stands of *Potamogeton*, *Brasenia*, *Nymphaea*, and *Nelumbo*.

7. Overcup oak (ON): forested habitats dominated (>60% areal coverage) by overcup oak (*Quercus lyrata*) and red maple (*Acer rubrum*). Swamp-privet (*Forestiera acuminata*) and waterlocust (*Gleditsia aquatica*) dominate the understory. Baldcypress and water tupelo trees are often scattered throughout ON habitats.

8. Overcup oak—GTR (OG): areas similar to ON habitats but within GTR's.

9. Pin oak-low (PL): forested habitats containing a mixture (<10–20% areal coverage of any of the following species) of overcup oak, red maple, pin oak (*Quercus palustris*) and cherrybark oak (*Quercus falcata* var. *pagodifolia*) trees. Baldcypress and water tupelo occur in low sites. Pin oak-low habitats within GTR's were not sampled.

10. Pin oak-high (PH): forested habitats dominated (>80% areal coverage) by pin oak, cherrybark oak, sweetgum (*Liquidambar styraciflua*), and willow oak (*Quercus phellos*). The understory is dominated by possumhaw (*Ilex decidua*), sugarberry (*Celtis laevigata*), and winged elm (*Ulmus alata*). The forest floor is mostly bare but annual and perennial plants of the Cyperaceae, Polygonaceae, and Poaceae occur in light gaps caused by tree falls and under younger trees where light penetration is sufficient.

11. Pin oak-high—GTR (PG): similar to PH habitats but within GTR's.

12. Pin oak/hickory (PHN): forested areas containing >30% areal coverage of shagbark hickory (*Carya ovata*) and >50% areal coverage of pin oak and sweetgum trees. Pin oaks are usually scattered in lower regions of PHN habitats. Vegetation in the understory includes common persimmon (*Diospyros virginiana*), honeylocust (*Gleditsia triacanthos*), and occasional sassafras (*Sassafras albidum*) and dogwoods (*Cornus* sp.). Ground cover is generally abundant, often with dense stands of poison ivy (*Toxicodendron radicans*).

13. Pin oak/hickory—GTR (PHG): similar to PHN habitats but within GTR's.

14. Scrub/Shrub (S/S): habitats dominated (>80% areal coverage) by buttonbush. A few baldcypress, water tupelo, and black willow (*Salix nigra*) trees are also usually present. *Bidens*, *Polygonum*, and *Leersia* grow in openings under the buttonbush when water levels recede to expose soil and permit germination. Dense mats of algae and submergent plants are present in sites that are

more permanently flooded. S/S habitats also often develop in older dead-tree habitats.

Field and Laboratory Work

Plots were visited in each of 118 weeks from 27 February 1981 to 27 May 1983. All 42 plots were visited weekly from October to May of each year and 9 of 42 plots (representing all six major habitat types) were visited weekly year-round. Four of the 42 plots could not be visited during the first 2 weeks of February 1982 because snow and ice made plots inaccessible. The following information was obtained for each habitat type at each visit by walking the entire plot and drawing water coverage maps.

1. percentage of the plot covered with water
2. percentage of the surface water $\leqslant$10, 11–20, 21–30, and >30 cm deep
3. number of puddles (i.e., noncontiguous water areas >1 m^2)
4. percentage of the surface water covered with ice

A surface water sample was taken from each plot each week (unless drying eliminated that site) and returned to the laboratory. Alkalinity (ppm) was determined by titrating 100 mL of the sample to a methyl purple endpoint with 0.02N H_2SO_4. Analyses of alkalinity were discontinued after week 66. pH was determined by using a Hach pH meter and was discontinued after week 100. Conductivity (μmhos) was analyzed with a Hach conductivity bridge. Light penetration (cm) was recorded by using a Secchi disk.

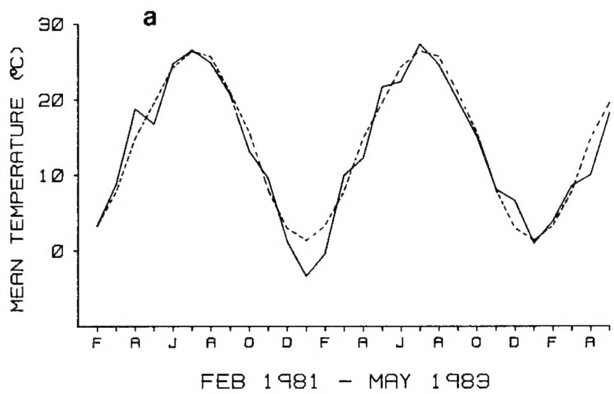
Data on the percentage of each plot in various habitat and subhabitat types, and the composition and diameter at breast height (dbh) of trees, were obtained in April and May 1981. Additional data were taken on composition and dbh of trees, number and sizes of light gaps, dbh and species of fallen trees, and composition of understory vegetation in May 1984. Light gaps are defined as vertical holes created by tree falls in the forest canopy extending to within at least 2 m of the forest floor (Brokaw 1982). Cover maps of light gaps were drawn in the field and the areas planimetered.

Data on water relations were analyzed for each of the 14 subhabitat types for all 118 weeks and within 10 climatological periods: (1) February–March 1981, (2) April–May 1981, (3) June–September 1981, (4) October–November 1981, (5) December 1981–March 1982, (6) April–May 1982, (7) June–September 1982, (8) October–November 1982, (9) December 1982–March 1983, and (10) April–May 1983. All precipitation amounts used in analyses were obtained from the Wappapello Lake recording station 3 miles from the southwestern boundary of MNWR.

Climatic Conditions During the Study

The climate of the Mingo Swamp is continental with humid and warm temperate conditions (Krusekopf 1966). Temperatures during the study were near long-term means with the exception of December 1981 through February 1982, when temperatures were below normal (Fig. 3a). Precipitation was erratic but was generally similar to long-term monthly means (Fig. 3b).

Most of the annual precipitation in the Upper MAV occurs from October through April (U.S. Department of Commerce 1966–84). Winter precipitation amounts differed during the 3 years of this study (Fig. 4). Winter 1980–81 was the driest since 1966–67 (Fig. 4); winter 1981–82 was wetter than 1980–81 but below long-term averages; and winter 1982–83 was the wettest, with precipitation (57.9 cm) exceeding long-term means.



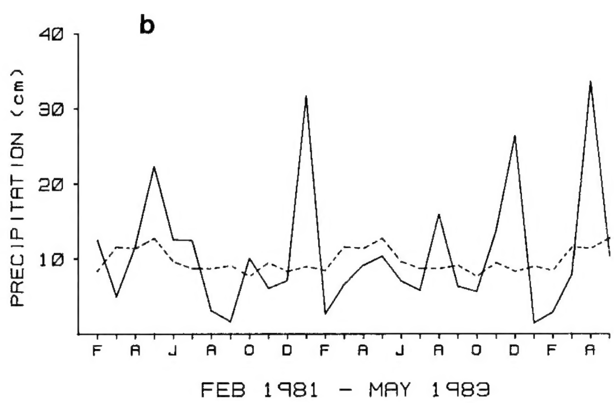


Fig. 3. Mean 1921 (*dashed line*) and February 1981–May 1983 (*solid line*) (a) monthly temperatures and (b) cm of precipitation for the Mingo Swamp.

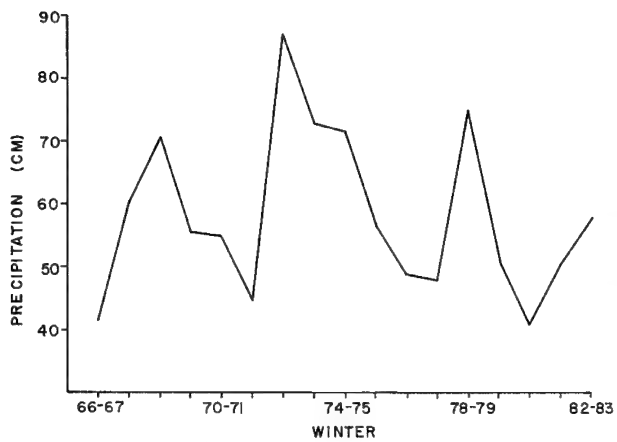


Fig. 4. Precipitation (cm) in the Mingo Swamp in winter (October–March) 1966–67 to 1982–83.

Results

Area and Distribution of Present Habitat Types

The primary habitat type in the Mingo Swamp is live forest, composing 48.3% of the area (Table 1). Dead tree, GTR, S/S, OM, OW, and agricultural fields each compose >4%.

Habitat types are generally distributed along elevational gradients (Fig. 2). This distribution reflects the degree of water permanence and plant inundation at different elevations. Lands below 335 ft MSL are the lowest in the Mingo Swamp (excluding river and ditch channels) and the 335 ft contour approximates the boundary of Monopoly Marsh. S/S habitats are present at 335–336 ft elevation, usually along the edges of rivers, sloughs, and Rockhouse and Monopoly marshes. The two major blocks of S/S habitat are at the northeastern (Gumstump pool) and southeastern edges of Monopoly Marsh. Dead-tree habitats are present adjacent to some S/S habitats, at elevations near 336 ft, and along ditches 3–7 and 10.

Live forest occurs at higher elevations (336–344 ft) than OW, baldcypress, S/S, and dead-tree habitats and is present primarily in northeastern and southeastern sectors of the Mingo Swamp. The live forest is composed mainly of pin oak types (Table 2). Sloughs compose 3% of the forest area. Trees within the live forest are relatively uniform, most being 40–51 cm dbh (Table 3). Overcup oak sites have slightly larger trees than other forest types. Almost all of the DCWMA is above 339 ft and originally was pin oak forest (G. Brakhage, personal communication).

Table 1. *Hectares of floodable land[a] in the Mingo Swamp in relation to habitat type in 1983.*

Habitat type	Hectares	Percent of total
Live forest	4,502	48.3
Dead tree	456	4.9
Green-tree reservoir	530	5.7
Scrub/shrub	550	5.9
Open marsh	1,476	15.9
Open water	543	5.8
Ditches and rivers	100	1.1
Slough	154	1.7
Other[b]	1,001	10.7
Total	9,312	100.0

[a] Lands below 344 ft elevation.
[b] Includes pastures, agricultural fields, roads, borrow areas, and buildings.

Table 2. *Habitat composition (hectares ± SE, percentage of total in parentheses) of naturally flooded and green-tree reservoir forests in the Mingo Swamp.[a]*

Habitat	Naturally flooded	Green-tree reservoir
Slough[b]	138 ± 45 (3.0)	15 ± 6 (2.9)
Pin oak/hickory	1,136 ± 374 (24.4)	124 ± 49 (23.3)
Pin oak–high	1,253 ± 317 (26.9)	262 ± 45 (49.3)
Pin oak–low	1,541 ± 309 (33.1)	32 ± 16 (5.9)
Overcup oak	453 ± 187 (9.7)	91 ± 58 (17.2)
Light gaps[c]	135 ± 33 (2.9)	7 ± 2 (1.3)
Total	4,656	531

[a] Area determined by expanding the percentage of subhabitat types present on 2.02-ha plots to the total area of naturally flooded and green-tree reservoir forests.
[b] Includes sloughs within forests.
[c] Openings in the forest canopy and floor caused by the death of trees.

Table 3. *Mean size categories[a] of trees in five naturally flooded habitat types in the Mingo Swamp in 1983.*

Habitat type	Mean ± SE	Range
Slough	2.93 ± 0.13	2–5
Pin oak/hickory	3.05 ± 0.12	2–4
Pin oak–high	3.07 ± 0.10	2–5
Pin oak–low	2.85 ± 0.11	2–5
Overcup oak	3.34 ± 0.12	2–5
All forested area combined	3.01 ± 0.11	1–5

[a] Categories: 1 = <25 cm dbh, 2 = 26–38 cm dbh, 3 = 39–51 cm dbh, 4 = 52–64 cm dbh, and 5 = >64 cm dbh.

Table 4. *Mean (± SE) number and area (hectares) of light gaps per hectare in naturally flooded and green-tree reservoir forests.*

Habitat	Naturally flooded		Green-tree reservoir	
	Number/ha	Area/ha	Number/ha	Area/ha
Slough	0.81 ± 0.5	0.04 ± 0.02	4.20	0.03
Pin oak/hickory	0.15 ± 0.1	0.01 ± 0.004	0.00	0.00
Pin oak-high	0.16 ± 0.1	0.01 ± 0.004	0.12 ± 0.1	0.01 ± 0.01
Pin oak-low	0.27 ± 0.1	0.02 ± 0.004	1.00	0.03
Overcup oak	0.40 ± 0.2	0.02 ± 0.01	0.00	0.00
All forest area combined	0.23 ± 0.1	0.01 ± 0.004	0.14 ± 0.04	0.004 ± 0.01
Analyses of variance—tests for differences among habitats	$P < 0.001$	$P < 0.01$	Insufficient data to test for differences	

Characteristics of Light Gaps

Light gaps compose 2–3% of the live-forest area in the Mingo Swamp (Table 2). More and bigger light gaps ($P < 0.01$) occur in habitats at lower elevations (i.e., in ON and PL habitats and along slough banks; Tables 4 and 5). The number and area of light gaps per hectare was correlated ($P < 0.05$) with the mean size of trees in all habitats except ON (Table 5). The 59 light gaps on the 42 study plots contained 68 fallen trees. Only 9 (13%) of the 68 fallen trees were uprooted; the remaining 59 (87%) were broken (main trunk split) 1–5 m from the ground. The mean (± SE) dbh of the fallen trees was 56 ± 6.7 cm for willow oaks, 64 ± 2.3 cm for pin oaks, 67 ± 5.4 cm for sweetgums, 69 ± 7.2 cm for overcup oaks, 49 cm for one ash, and 38 cm for one shagbark hickory. The mean dbh of the fallen trees was greater ($P < 0.05$) than the mean dbh of living trees.

Table 5. *Correlation coefficients between tree size category*[a] *of forested habitats and the number and area of light gaps per hectare within the Mingo Swamp.*

Habitat	Number/ha	Area/ha
Slough	0.191***[b]	0.206***
Pin oak/hickory	0.293*	0.195*
Pin oak-high	0.192*	0.185*
Pin oak-low	0.317***	0.245***
Overcup oak	0.016	0.139
All naturally flooded forests	0.106***	0.121***
Pin oak-high—GTR	0.404*	0.389
All green-tree reservoir forests	0.176**	0.183*

[a]Categories: 1 = <25 cm dbh, 2 = 26–38 cm dbh, 3 = 39–51 cm dbh, 4 = 52–64 cm dbh, 5 = >64 cm dbh.
[b]Levels of significance, Spearman's Rho tests: * = <0.05, ** = <0.01, *** = <0.001.

Water Regimes

Water Coverage and Depth

River, ditch, OW, and DO habitats were more permanently flooded than other habitats (Fig. 5; Table 6). These habitats were flooded during most of the year, but the edges of ditch and river channels and DO basins dried and water depths became shallower in summer. S/S, OM, and DN habitats were less permanently flooded than river, ditch, and DO habitats but still contained some water >80% of the year and >65% of the growing season (Fig. 5; Table 6). ON habitats were flooded longer and deeper than other naturally flooded forest habitats. Some flooding of ON habitats occurred from November to April each year. ON habitats were 100% flooded in late winter. Flooding of OG habitats was generally longer and deeper than in ON sites, especially during the growing season.

PL habitats were usually partly flooded from December through May, but were seldom 100% flooded (Fig. 5; Table 6). Water within PL habitats was typically 10–20 cm deep but became deeper in late winter and early spring and dried in summer. PH habitats were partly flooded for >60% of the year and 40% of the growing season. PH habitats were usually flooded 10–20 cm deep from January to April. PG habitats were flooded longer and deeper than PH habitats. PHN habitats were flooded for shorter periods than other habitats. Typically, flooding of forests at higher elevations was shallow or of short duration and associated with periods of river overflow and headwater flooding in late winter.

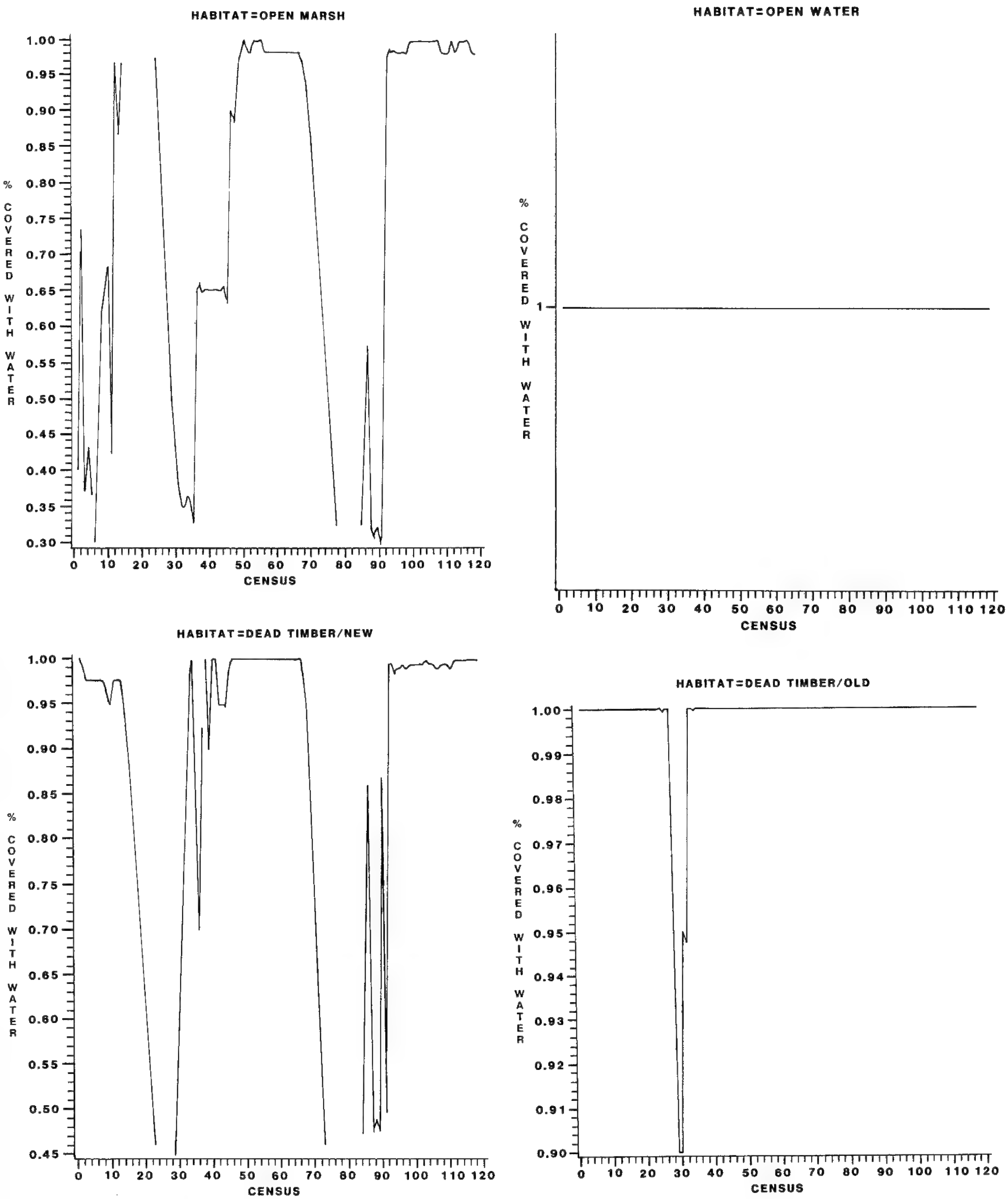


Fig. 5. Percentage of 12 habitat types within the Mingo Swamp that were covered with surface water 27 February 1981 (census 1)–27 May 1983 (census 118).

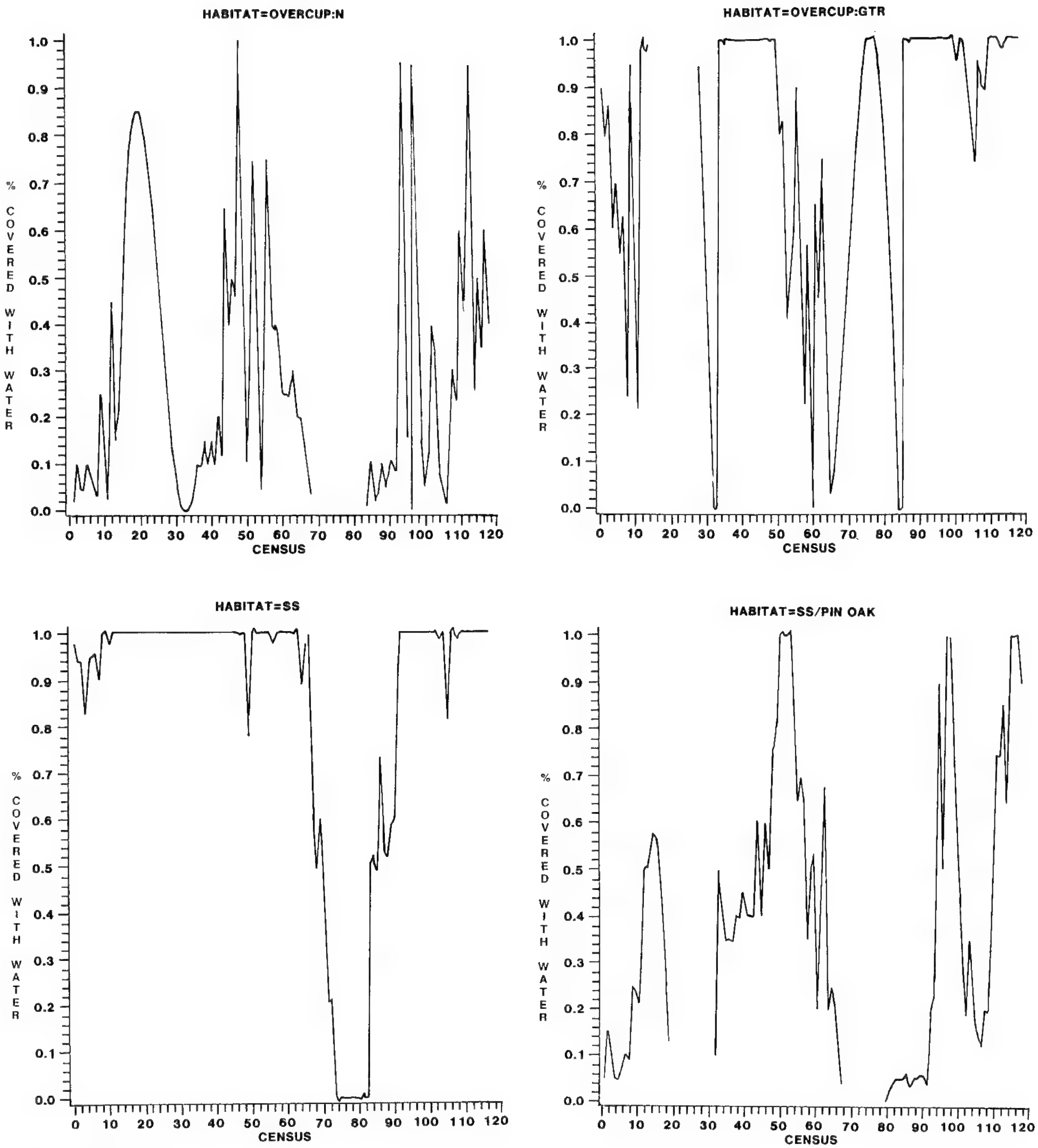


Fig. 5. *Continued.*

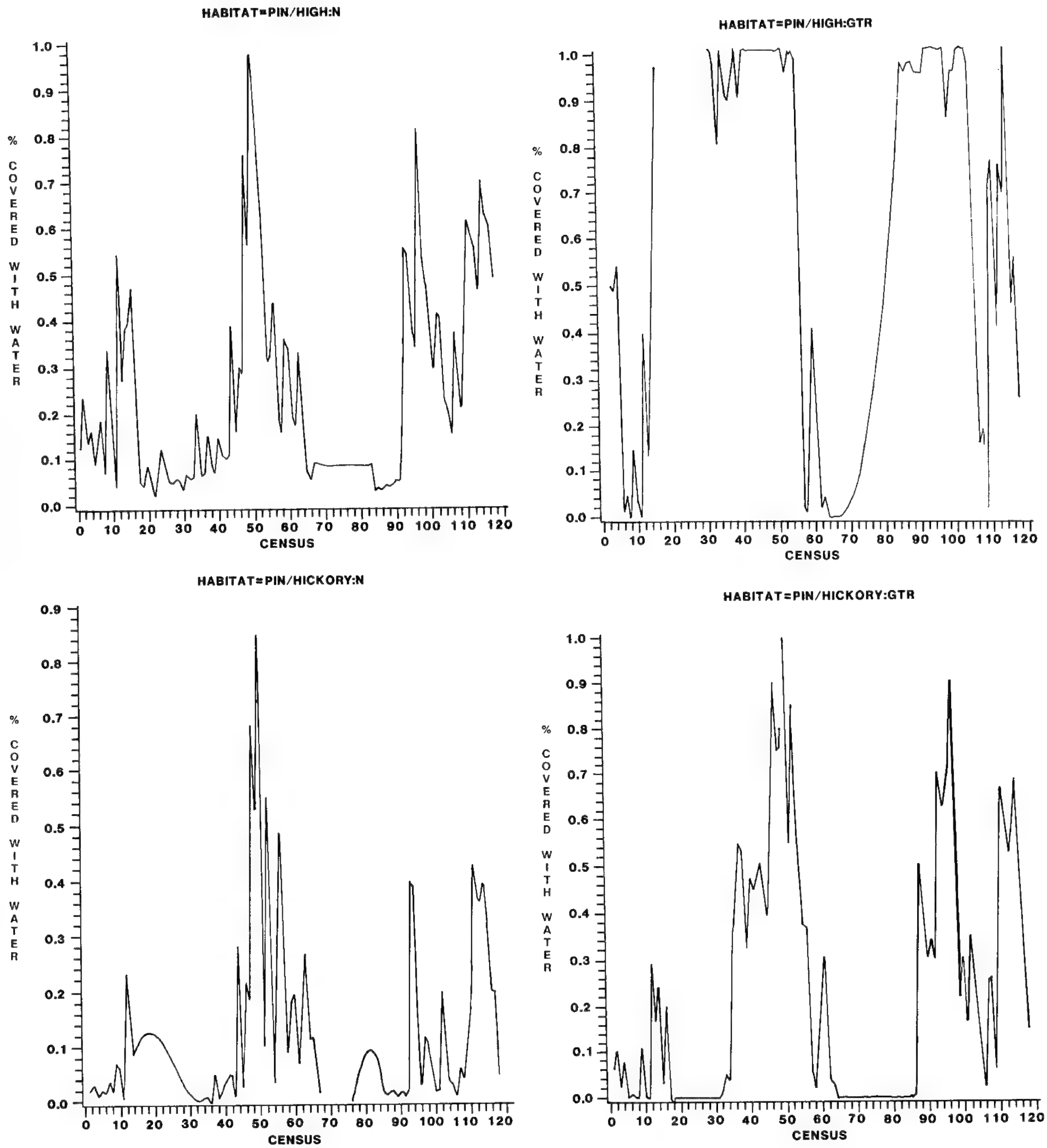


Fig. 5. *Continued.*

Table 6. *Percentage of time that habitat types within the Mingo Swamp were 100%, 50%, and 10% flooded in February 1981–May 1983 (total) and April–September 1981 and 1982 (growing season). Sample sizes reflect weeks surveyed.*

	Area flooded (total) $n = 118$			Area flooded (growing season) $n = 52$		
Habitat type	10%	50%	100%	10%	50%	100%
Dead tree–new	88.7	84.7	38.9	65.4	59.2	19.2
Dead tree–old	100.0	100.0	92.3	100.0	100.0	82.6
Ditch	100.0	100.0	24.6	100.0	100.0	13.7
River	100.0	100.0	32.0	100.0	100.0	22.6
Open marsh	100.0	77.1	12.7	100.0	80.7	0.0
Open water	100.0	100.0	100.0	100.0	100.0	100.0
Overcup oak—GTR[a]	94.9	84.7	37.2	88.4	71.1	5.7
Overcup oak—N[b]	72.0	22.9	3.3	53.8	17.3	0.0
Pin oak/hickory—GTR	43.2	15.2	0.8	15.3	0.0	0.0
Pin oak/hickory—N	38.1	3.3	0.0	26.9	0.0	0.0
Pin oak–high—GTR	85.5	61.8	33.9	61.5	19.2	3.8
Pin oak–high—N	61.8	16.9	0.0	40.3	1.7	0.0
Pin oak–low—N	68.6	42.4	2.5	48.1	25.0	5.8
Scrub/shrub	88.9	86.4	60.2	75.0	69.2	38.5

[a]Green-tree reservoir.
[b]Naturally flooded.

Table 7. *Results of multiple regression analyses of the percentage of naturally flooded habitats in the Mingo Swamp*[a] *on precipitation amounts during the survey week (PCP), and the estimated percentage of the habitats flooded during the previous week (HPCW).*

Period	Partial F-test OSL's	Equation	P	R^2
February–March 1981	PCP = 0.003 HCPW = 0.012	Y = 0.25 + 0.12(PCP) + 0.32(HCPW)	0.005	0.99
April–May 1981	PCP = 0.0001 HCPW = 0.002	Y = 0.15 + 0.08(PCP) + 0.47(HCPW)	0.0001	0.96
June–September 1981	PCP = 0.675 HCPW = 0.034	Y = 0.19 + 0.01(PCP) + 0.54(HCPW)	0.093	0.33
October–November 1981	PCP = 0.398 HCPW = 0.192	Y = 0.14 + 0.03(PCP) + 0.59(HCPW)	0.191	0.27
December 1981–March 1982	PCP = 0.019 HCPW = 0.008	Y = 0.20 + 0.04(PCP) + 0.63(HCPW)	0.0003	0.68
April–May 1982	PCP = 0.202 HCPW = 0.126	Y = 0.03 + 0.10(PCP) + 0.892(HCPW)	0.188	0.34
June–September 1982	PCP = 0.864 HCPW = 0.0001	Y = 0.07 − 0.01(PCP) + 0.74(HCPW)	0.0005	0.66
October–November 1982	PCP = 0.071 HCPW = 0.163	Y = 0.05 + 0.10(PCP) + 1.06(HCPW)	0.138	0.48
December 1982–March 1983	PCP = 0.0001 HCPW = 0.0002	Y = 0.23 + 0.05(PCP) + 0.54(HCPW)	0.0001	0.82
April–May 1983	PCP = 0.061 HCPW = 0.341	Y = 0.55 + 0.02(PCP) + 0.19(HCPW)	0.128	0.49

[a]Dependent variable.

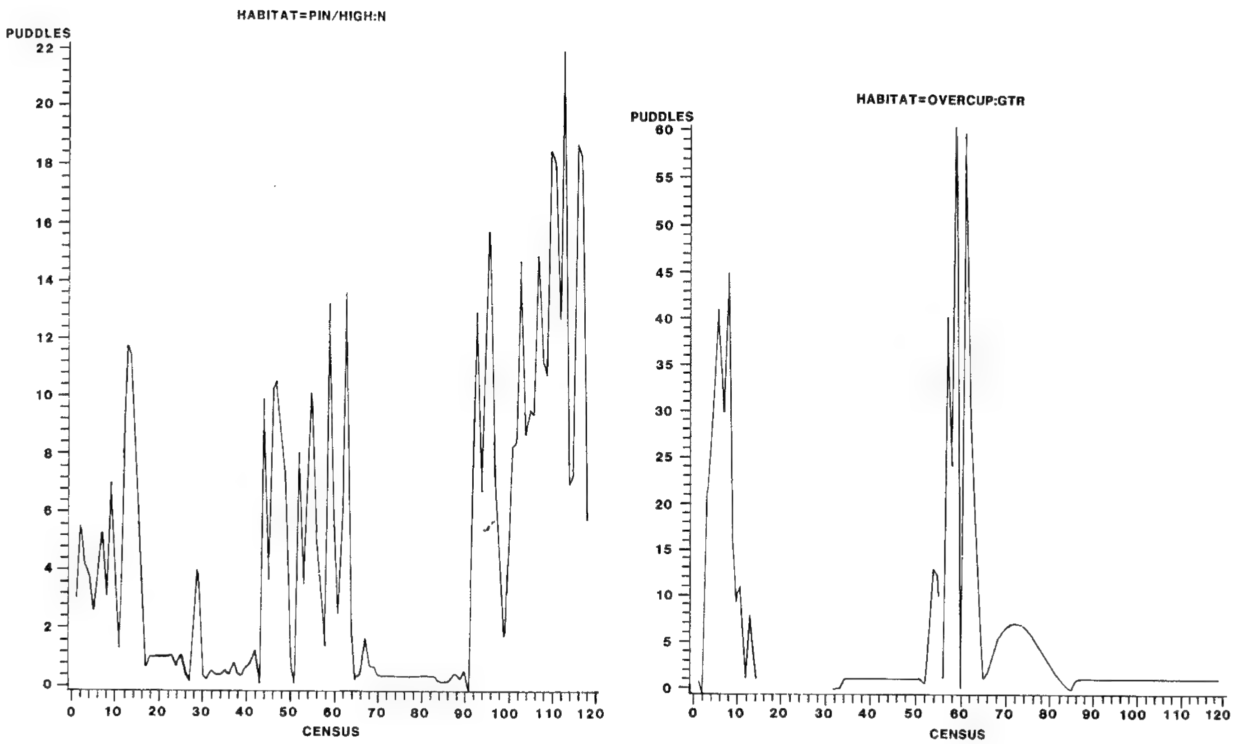


Fig. 6. Mean number of puddles present on 2.02-ha plots in pin oak–high and overcup oak—GTR habitats within the Mingo Swamp, 27 February 1981 (census 1)–27 May 1983 (census 118).

Total area flooded in the Mingo Swamp was related to seasonal precipitation (Table 7). Water depth on plots was correlated ($P < 0.05$) with precipitation amounts during both the week of and the week before surveys. All area and depth correlations were strongest in winter. Because of increased rainfall in winter 1982–83, all habitats were flooded earlier, deeper, and more completely (Fig. 5). Area flooded in summer was largely dependent on carry-over from spring and to a lesser extent on summer precipitation (Table 7). Water levels in fall 1981 were dependent more on carry-over from summer flooding, whereas in fall 1982 precipitation during October and November was the primary factor affecting water levels (Table 7).

Puddles

More puddles were present in habitats with shorter periods of flooding (e.g., PH) than those with longer and more stable flooding (e.g., OG; Fig. 6). GTR's contained fewer ($P < 0.05$) puddles than naturally flooded forests. Puddles were present in GTR's only when flooding began in fall and again when GTR's were drained in late winter and spring. The number of puddles in naturally flooded forests was correlated with rainfall and the number of puddles the previous week (Table 8). Typically, as rainfall increased puddles joined together and decreased the total number present.

Light Penetration and Water Chemistry

Light penetration of waters in the Mingo Swamp was low and fluctuated greatly in all habitats (Fig. 7). Only OW had consistently clear water. In winter 1982–83, increased precipitation, river overflows, and runoff into the Mingo Swamp decreased light penetration in all habitats and for all water depths (e.g., light penetration [cm] in week x = 12.6 – 0.8 [precipitation in week x] + 0.7 [light penetration in week x – 1], $P < 0.001$).

Alkalinity fluctuated greatly over the year in all habitats but was consistently highest (>100 ppm) in ditches and naturally flooded forests (Fig. 8); alkalinity was usually <70 ppm in other habitats. Alkalinity was highest when water was shallow and concentrated. Alkalinity was negatively correlated with precipitation amounts in spring—for example, in April–May 1981 (alkalinity in week x = 32.2 – 7.2 [precipitation in week x] + 0.5 [alkalinity in week x – 1], $P < 0.001$).

Table 8. *Significant results (P < 0.05) of multiple regression analyses of the number of puddles on naturally flooded habitats in the Mingo Swamp*[a] *on precipitation amounts during the survey week (PCP) and the estimated number of puddles the previous week (PPW).*

Period	Partial *F*-test OSL's	Equation	*P*	R^2
April–May 1981	PCP = 0.033 PPW = 0.164	Y = 1.27 + 1.27(PCP) + 0.53(PPW)	0.085	0.56
June–September 1981	PCP = 0.667 PPW = 0.001	Y = 0.70 − 0.11(PCP) + 0.53(PPW)	0.005	0.58
October–November 1981	PCP = 0.606 PPW = 0.051	Y = 0.21 + 0.05(PCP) + 0.75(PPW)	0.083	0.50
June–September 1982	PCP = 0.294 PPW = 0.021	Y = 0.033 + 0.37(PCP) + 0.56(PPW)	0.021	0.42
October–November 1982	PCP = 0.005 PPW = 0.044	Y = 2.43 + 2.88(PCP) − 2.56(PPW)	0.014	0.76

[a]Dependent variable.

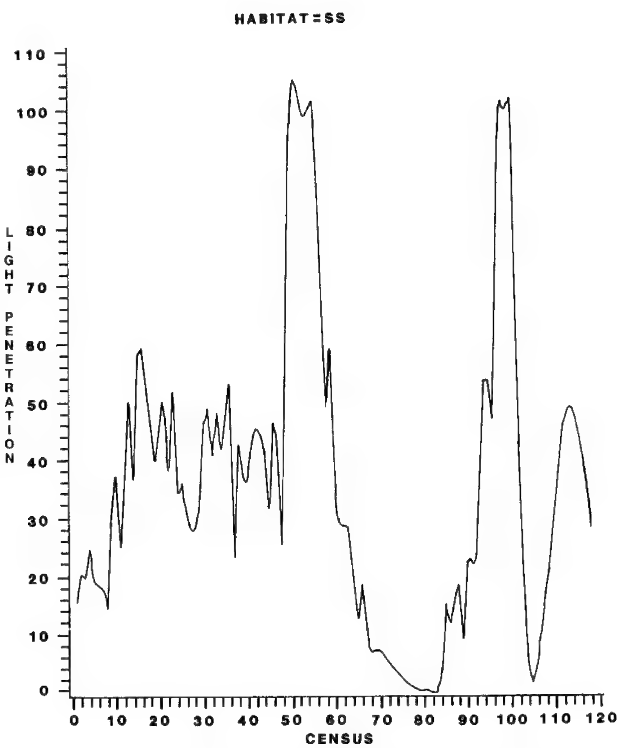


Fig. 7. Mean light penetration (cm) of surface waters in scrub/shrub habitats within the Mingo Swamp 27 February 1981 (census 1)–27 May 1983 (census 118).

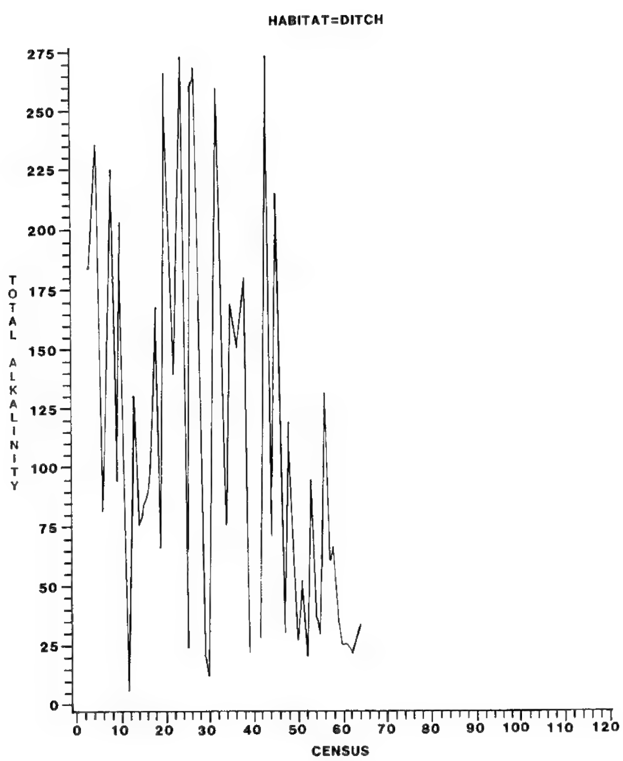


Fig. 8. Mean total alkalinity (ppm) of surface waters in ditches within the Mingo Swamp, 27 February 1981 (census 1)–27 May 1983 (census 118).

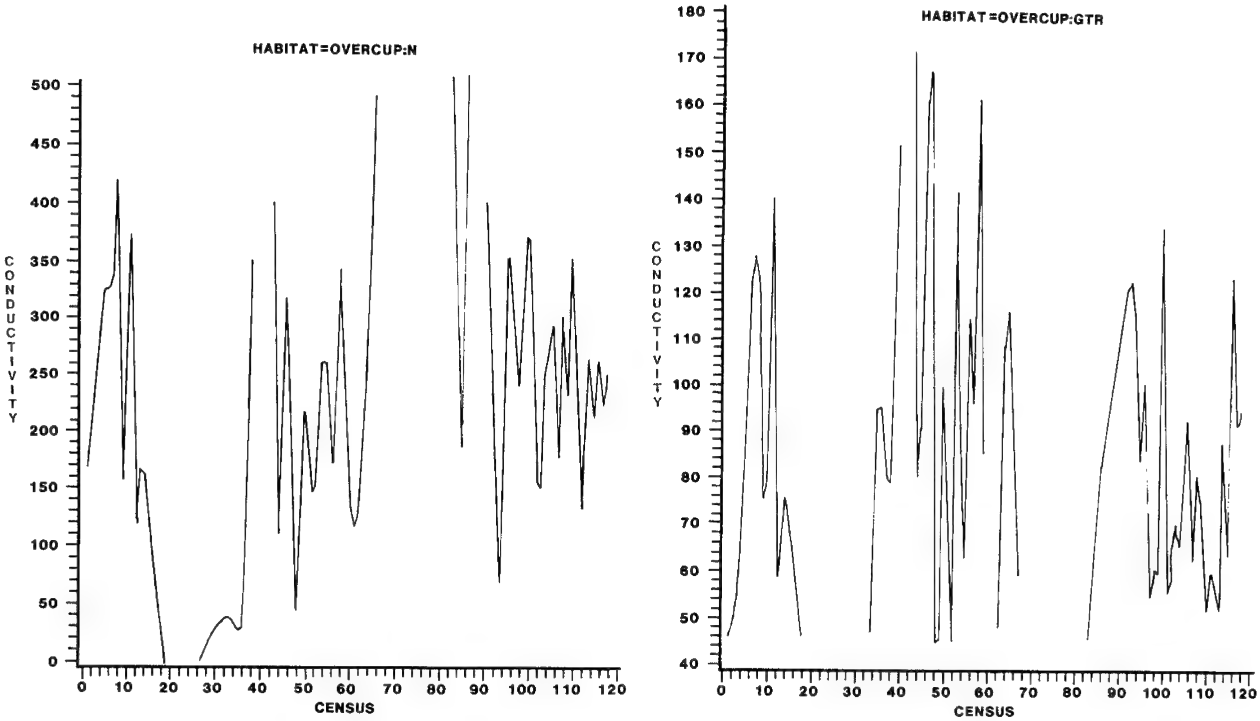


Fig. 9. Mean conductivity (μmhos) of surface waters in overcup oak habitats within the Mingo Swamp, 27 February 1981 (census 1)–27 May 1983 (census 118).

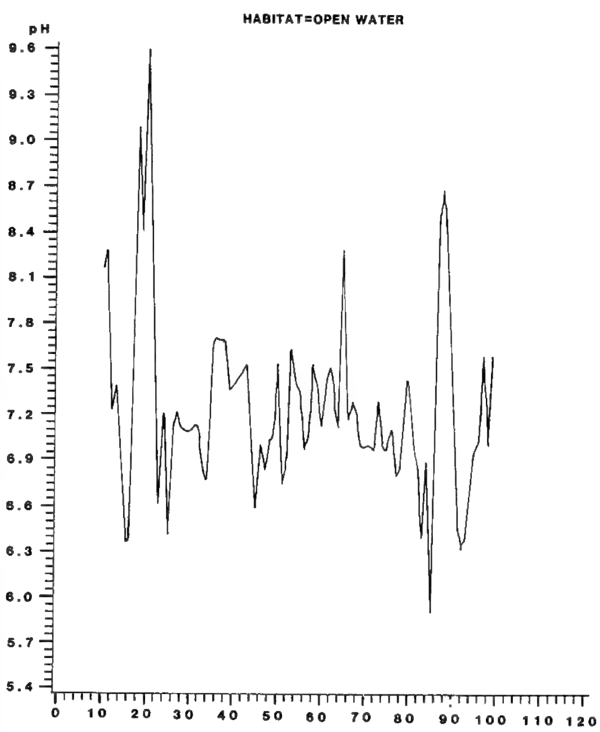


Fig. 10. Mean pH of surface waters in open-water habitats within the Mingo Swamp, 27 February 1981 (census 1)–27 May 1983 (census 118).

GTR habitats, especially OG, had consistently lower alkalinities than naturally flooded forests.

Conductivity varied over the year in all habitats and was generally highest in late summer and fall (Fig. 9). Ditches, rivers, and ON habitats had consistently higher conductivity than other habitats. Conductivity was highest when water levels were lowest. Conductivity was often negatively correlated with precipitation—for example, in April–May 1981 (conductivity in week x = 57.9 – 15.5 [precipitation in week x] + 0.6 [conductivity in week x – 1], $P < 0.001$).

pH of waters was also variable among weeks and habitats (Fig. 10). OW habitats often experienced great differences in pH between weeks. pH was highest in habitats with more permanent water (i.e., OW, rivers, ditches, dead tree, and ON). Pin oak habitats generally had low pH values. pH generally declined during initial flooding in forest and S/S habitats in late fall and early winter and stayed low until spring when rainfall increased.

Ice Cover

Ice was present on wetlands in the Mingo Swamp for only 2 weeks in February 1981, 4 weeks in January and

February 1982, and 4 weeks in January and February 1983 (Fig. 11). Rivers, ditches, OW, and naturally flooded forests had less ($P < 0.0001$) ice cover than other wetlands (Table 9). Water in dead-tree and GTR habitats froze earlier and thawed later ($P < 0.01$) than other habitats.

Historical Area and Habitat Change

The floodable lands of the Mingo Swamp have undergone dramatic change since 1880 (Table 10). The greatest change is the decline in live-forest area from 82.1% to 48.3% from 1880 to 1983. In 1880, few people lived in or near the Mingo Swamp, little timber had been cut, natural drainage systems were intact, and no roads or ditches were present (Forrister 1970). A large area of open baldcypress with little understory was present below 335 ft MSL (the present basin of Monopoly Marsh) in 1880 (Widmann 1907). S/S habitats were limited to edges of sloughs, rivers, and natural ponds or low areas and, likewise, dead trees were limited to small areas where water regimes changed to become more permanent.

Logging and timber-cutting began in the Mingo Swamp in the late 1880's (Forrister 1970). By 1920, most of the forests had been cut over, some roads and ditches were built, and attempts were being made to farm portions of the cleared lowlands. By 1941 (when the first aerial photographs were taken), all of the forests had been cut over and 1,524 ha of forest and open

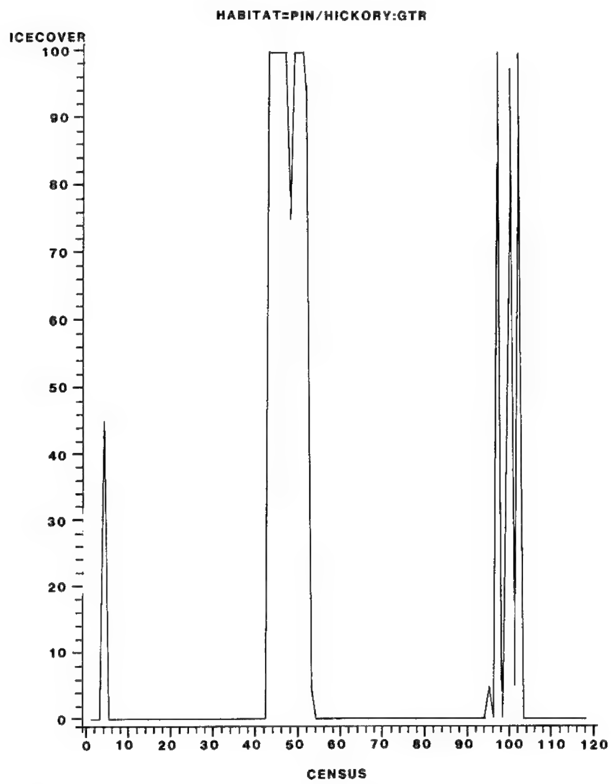


Fig. 11. Percentage of flooded pin oak/hickory—GTR habitats that were covered with ice 27 February 1981 (census 1)–27 May 1983 (census 118).

Table 9. *Mean percentage of ice cover on habitat types within the Mingo Swamp in winter 1981–83.*

Habitat type	February–March 1981	December 1981–March 1982	December 1982–March 1983
Dead tree–new	0.00[a]	54.14	17.66
Dead tree–old	0.00	61.11	19.06
Ditch	0.00	9.70	0.62
River	0.00	44.85	20.33
Open marsh	0.00	50.98	18.24
Open water	0.00	55.29	3.92
Overcup oak—GTR[b]	4.00	50.29	21.18
Overcup oak—N[c]	0.00	36.25	16.76
Pin oak/hickory—GTR	9.00	57.21	19.26
Pin oak/hickory—N	0.00	34.39	14.01
Pin oak-high—GTR	0.00	58.53	17.94
Pin oak-high—N	0.00	40.33	19.74
Pin oak-low	0.00	42.99	13.72
Scrub/shrub	0.00	56.77	16.18

[a]The mean percentage of ice cover was different (AOV tests, $P < 0.0001$) among habitat types in all winters.
[b]Green-tree reservoir.
[c]Naturally flooded.

Table 10. *Hectares (percentage of total in parentheses) of floodable land*[a] *in the Mingo Basin in 1880, 1941, 1955, 1966, 1973, and 1983 in different habitat types.*

Habitat type	1880[b]	1941	1955	1966	1973	1983
Live forest	7,647(82.1)	5,868(63.0)	6,264(67.3)	5,883(63.2)	5,466(58.7)	5,033(54.0)
Naturally flooded	7,647(82.1)	5,868(63.0)	5,206(55.9)	5,234(56.2)	4,898(52.6)	4,502(48.3)
Green-tree reservoir	0	0	1,058(11.4)	649(7.0)	568(6.1)	531(5.7)
Dead tree	23(0.2)	10(0.1)	10(0.1)	21(0.2)	95(1.0)	456(4.9)
Scrub/shrub	279(3.0)	541(5.8)	345(3.7)	272(2.9)	483(5.2)	550(5.9)
Open baldcypress	1,012(10.9)	1,000(10.7)	1,147(12.3)	1,083(11.6)	1,016(11.4)	1,006(10.8)
Open water	0	4(0.1)	4(0.1)	409(4.4)	490(5.3)	543(5.8)
Slough and pond	279(3.0)	224(2.4)	219(2.3)	206(2.2)	182(2.0)	154(1.6)
River	70(0.8)	43(0.5)	40(0.4)	37(0.4)	36(0.4)	33(0.4)
Managed marsh	0	0	0	0	81(0.9)	469(5.0)
Ditch	0	67(0.7)	67(0.7)	67(0.7)	67(0.7)	67(0.7)
Road	0	23(0.3)	121(1.3)	151(1.6)	179(1.9)	190(2.0)
Borrow area	0	0	10(0.1)	34(0.4)	34(0.4)	34(0.4)
Agricultural field	0	1,524(16.4)	1,078(11.6)	1,133(12.2)	1,121(12.0)	757(8.1)
Other[c]	0	6(0.1)	8(0.1)	14(0.2)	18(0.2)	20(0.2)

[a] Lands below 344 ft elevation (totals 9,312 ha).
[b] See text for estimation procedure.
[c] Buildings, parking lots, etc.

baldcypress had been cleared for agricultural fields. S/S habitats were present in low cutover areas. The 15 ditches dug during the 1920's reduced sloughs and natural ponds by 55 ha and rivers by 27 ha; concurrently, ditches increased by 67 ha and roads by 23 ha between 1880 and 1941. Area in live forest decreased 1,779 ha between 1880 and 1941 (Table 10).

Fires were common in the Mingo Swamp in the early 1900's, and three extensive burns occurred in the early 1940's (MNWR, unpublished records). The MNWR was officially created in 1945, and further development in the Mingo Swamp began at this time. Between 1941 and 1955, 97 ha of roads and levees and 10 ha of borrow area were created (Table 10). These roads and levees impeded water flow through the swamp and reduced the area of rivers and sloughs. A total of 446 ha were removed from agricultural use and allowed to regenerate to live forest and open cypress between 1941 and 1955. As trees matured, S/S acreage declined. The Duck Creek Wildlife Management Area (DCWMA) was established in 1950, and by 1955 construction of levees around Pools 1–3 was completed, creating 1,058 ha of GTR (519 ha in Pools 2 and 3; 538 ha in Pool 1—other acreage in Pool 1 was S/S, dead tree, and OW).

The major change in habitat composition between 1955 and 1966 was the decline of GTR area as most of the forest in Pool 1 died creating an additional 405 ha of OW (Table 10). S/S area declined further as forests regenerated in higher sites. Road, levee, and borrow area construction increased along ditches 2–4 in the early 1960's. Area in rivers and sloughs gradually declined, and by 1966 a major increase in dead-tree habitats began.

Forest, open baldcypress, slough, and river areas decreased between 1966 and 1973 (Table 10). By 1973, 81 ha of managed seasonally flooded impoundments were operational and road and levee area increased further. The addition of roads and levees between 1955 and 1973 severely impeded waterflow and created more prolonged flooding of many live-forest areas, causing trees to die and increasing dead-tree and S/S area.

By 1983, waterflow through the Mingo Swamp was slowed and controlled by water control structures creating more permanent water regimes, killing live forest (in both natural and GTR areas) and creating more dead-tree and S/S habitats. More than 324 ha of agricultural fields were converted to seasonally flooded impoundments. Area in roads and levees increased from

1973 to 1983, while area in sloughs and rivers declined (Table 10).

Discussion

Distribution of Habitats

The present study further documents that the timing, depth, duration, and extent of flooding determines the vegetation composition and distribution within southern forested wetlands (Fredrickson 1979c, 1980; Clark and Benforado 1981). Within the Mingo Swamp and in most other forested wetlands, water permanence is related to elevation, with lower elevations being flooded at greater depths and for longer periods. These more permanent water regimes support more water-tolerant vegetation such as baldcypress, water tupelo, buttonbush, and swamp-privet. Higher elevations support lowland forests that eventually grade into water-intolerant upland communities.

Drainage within the Mingo Swamp is poor and is strongly influenced by sedimentation patterns occurring on the historic floodplain of the Mississippi River. Numerous meander scars, depressions, and uplifts (old point bars, sand boils, natural river levees) within the Mingo Swamp create a mosaic of elevations and, consequently, an interspersion of habitat types within larger well-defined elevational gradients. This interspersion makes the concept of lowland hardwood habitat type "bottoms" or "zones" (Larson et al. 1981) somewhat difficult in the Mingo Swamp.

Within the "mosaic" of habitat types many different tree species with different water tolerances are often found within an area that is generally dominated by one or two species. This interspersion of tree species may be created and maintained by constantly changing drainage patterns. As drainages experience changes in waterflow because of erosion and flooding, sediments are redistributed across the floodplain. This redistribution and deposition of sediments creates small ridges, hummocks, and natural levees that may support a slightly different species composition than those that occur on immediately adjacent sites. These "drainage dynamics" and their effects on habitat and forest interspersion are similar to, but less dramatic than the larger "river dynamics" of floodplains of tropical lowland forest ecosystems (Salo et al. 1986).

Drainage dynamics may also cause some tree falls and further promote habitat and tree species heterogeneity. Our data suggest that at least 2–3% of lowland hardwood forests is composed of light gaps at any given time. The area composed of light gaps in mature tropical lowland floodplain forests may exceed 5% (Hartshorn 1980; Uhl and Murphy 1981). Fallen trees within the Mingo Swamp are most often trees that are less water tolerant, such as pin oak and willow oak. It is possible that these trees germinated and matured on less than optimal sites during dry periods of long-term precipitation trends; then, when they encountered wetter regimes, loss of vigor or mortality occurred.

Flooding

Rainfall within the MAV is highly variable. As with most south-central and southeastern regions of the United States, the Mingo Swamp receives most of its annual rainfall between November and April. Consequently, most forested wetlands are flooded in winter but are dry in summer and early fall when evapotranspiration is high and rainfall reduced. Dry summer periods allow trees that were flooded in their dormant season (October–March) to survive and make possible the germination and establishment of new seedlings. All forested habitats, including the relatively water-intolerant PHN type, are often inundated for short periods of the growing season in some years—usually in spring—but flooding does not continue for extensive periods or occur every year. Recent studies indicate that relatively water-intolerant species such as pin oaks can tolerate short periods of inundation in spring (Hook and Scholtens 1978; Black 1984).

Long-term precipitation trends within lowland hardwood wetlands indicate that regular peaks and lows occur every 4 to 6 years in winter (U.S. Department of Commerce 1966–84). These long-term fluctuations help regulate lowland hardwood ecosystems and maintain habitat diversity and stability. Most wetlands require periodic drying and flooding to maintain nutrient flow (Klopatek 1978; Weller 1978; Mitsch et al. 1979). In contrast with prairie wetlands (Van der Valk and Davis 1978; Weller 1978), the biomass and structure of vegetation in lowland hardwood wetlands changes little between dry and wet periods of long-term precipitation change. Thus, the seasonal and among-years fluctuations in water levels common to southern forested wetlands are great and play an important role in the distribution and production of vegetation just as they do in other North American wetland types.

Waters that flood lowland hardwood wetlands come from three types of flooding: (1) on-site rainfall and puddling, (2) backwater flooding, and (3) headwater flooding, also referred to as flash flooding (Fredrickson 1979c, 1980). On-site rainfall is precipitation of suffi-

Table 11. *Flooding characteristics of naturally flooded scrub/shrub and forested habitats in the Mingo Swamp during a dry (1981) and a wet (1983) year.*

Habitat and water condition	Length of flooding	Average depth (cm)			Type of flooding[a]		
		October	December	March	October	December	March
Scrub/shrub							
Dry	October–June	10–20	30	30	R	R/B	R/B
Wet	Year-round	20–30	30	30	B	B/H	B/H
Overcup oak							
Dry	October–May	10	20–30	30	R	R/B	R/B
Wet	September–July	10–20	20–30	30	R	R/B/H	B/H
Pin oak–low							
Dry	December–May	Dry	10	10–20	—	R	R/B
Wet	November–June	Dry	10–20	20–30	—	R/B/H	B/H
Pin oak–high							
Dry	January–May	Dry	Dry	10–20	—	—	R/B
Wet	November–June	Dry	10	10–20	—	R/B	B/H
Pin oak/hickory							
Dry	January–April	Dry	Dry	10	—	—	R/B
Wet	November–May	Dry	10	10–20	—	R/B	B/H

[a]R = on-site rainfall, B = backwater flooding, H = headwater flooding.

cient quantity falling directly on an area to flood dry areas. If little rain falls, usually only depressions in the forest floor (puddles) are flooded. This type of flooding is typical in late fall and occurs in low areas. Backwater flooding occurs as drainage systems become filled beyond their capacity after heavy rains. Backwater flooding typically occurs every 1 to 2 years, usually in late winter or spring, and probably every year during the highs of long-term winter water cycles. Headwater flooding results from extremely heavy rains over a short time throughout upstream watersheds and floodplains. Large inflows of water from upstream as well as from heavy local precipitation fill basins to capacity in a few days or sometimes within a few hours. Frequency of these floods averages 4 to 6 years, and they are most common in late winter, spring, and early summer.

These different types of flooding influence forested wetlands in different ways. On-site flooding contributes water but few nutrients to lowland hardwood wetlands (Brinson et al. 1980). The shallow depressions where puddles form are important inoculum sites for crustaceans (White 1985). These puddles provide a medium for initial growth and reproduction of invertebrates in fall and winter and serve as damp areas for aestivation and dormancy of adults and eggs in summer and early fall. On-site rainfall is especially important for flooding pin oak habitats in the Mingo Swamp in late fall (Table 11). Backwater flooding inundates large areas of lowland forests and deposits large amounts of fine sediments and nutrients to forested wetlands (Mitsch 1979; Mitsch et al. 1979; Clark and Benforado 1981). Backwater flooding is important in almost all habitats in the Mingo Swamp, but lower and deeper habitats are typically flooded first (Table 11). Unless flooding is extensive, higher elevations are not inundated until later in winter. Headwater floods usually inundate all habitats because of the large volume of water occurring in a short time. Little is known about nutrient fluxes caused by this type of flooding, but it may export rather than import nutrients if water flow is rapid and scouring takes place.

Water Chemistry

Alkalinity, conductivity, pH, and light penetration of waters in the Mingo Swamp were variable. The erratic nature of chemical concentrations in all habitats was probably caused by the great fluctuations in water regimes. Factors influencing chemical concentrations are rainfall, summer evapotranspiration (Fredrickson 1980), decomposition of leaf litter (Brinson et al. 1980), the stable biomass that continually extracts nutrients from soil and water (Wharton et al. 1982), and the source of flood water (Mitsch et al. 1979).

Alkalinity, conductivity, and pH were all relatively low in the Mingo Swamp waters compared with many other freshwater wetlands (cf. Wetzel 1975). These low concentrations seem related to the importance of on-site rainfall to lowland hardwood wetlands, the geological composition of the limited watershed that drains into Mingo Swamp, and the huge annual input of forest litter into these wetlands (Wylie and Jones 1986). Highest alkalinity and conductivity occurred in ditch, river, and ON habitats. Water tends to accumulate and remain in these habitats during drawdown periods, thus concentrating nutrients and runoff from surrounding watersheds.

Alkalinity and conductivity were generally greatest during low water, and concentrations were negatively correlated with rainfall. Increasing water levels and volume dilute chemical concentrations, whereas decreasing water levels increase chemical concentrations (cf. Wetzel 1975; Heitmeyer and Vohs 1981). Most waters became more acidic in fall and winter as a result of decomposition of autumn-shed leaves and other forest litter (Kaushik and Hynes 1968, 1971; Mitsch et al. 1979).

The similarity of levels of chemicals among the wetland types within the Mingo Swamp (excluding rivers and ditches) apparently indicates that water and nutrients flow freely among wetland types, especially during backwater flooding. Water in GTR habitats had lower chemical concentrations in winter than did naturally flooded forests. Altered water regimes in GTR's caused by rapid flooding in fall and reduction of backwater flooding may cause these lower chemical concentrations. The lower pH of GTR waters may reflect longer flooding and decomposition of forest litter.

Historical Perspective of Wetlands in the Mingo Swamp and the Upper Mississippi Alluvial Valley

Mingo Swamp

The Mingo Swamp has been an area of lower elevation and poorer drainage than most other areas of the Upper MAV since the Mississippi River changed its course about 18,000 B.P.. The watershed of the Mingo Swamp is small and the drainage system of the area in the late 1800's was probably similar to that shown in Fig. 12. Most water draining into the swamp comes from the surrounding Ozark Hills, with lesser amounts from Crowley's Ridge. As judged by recent periods of high water in 1973 and 1976, water also probably backed into the swamp from the St. Francis and Castor rivers in historic times. Water from the Mississippi River may also have flowed through the Advance Lowlands and into the Mingo Swamp during major floods. The numerous small tributaries flowing into the Mingo Swamp formed many braided shallow meanders that drained into the deeper-ponded areas of Monopoly Marsh (Fig. 12). When water was high, water drained out of Monopoly Marsh into the Mingo River.

The relatively poor drainage of the Mingo Swamp created two large areas of open baldcypress habitat in the lowest elevations (Monopoly and Rockhouse basins). Habitats surrounding these two low basins were forested. Pin oak habitats probably composed >75% of the forest area. S/S habitats surrounded natural ponds and deeper sloughs. There is little evidence that extensive areas of dead trees were present in the Mingo Swamp in the late 1800's. Areas too wet to support oaks probably would have succeeded to open baldcypress or S/S habitats over time. As previously discussed, drainage and elevational changes occurred regularly within forests in the Mingo Swamp, and probably altered water regimes sufficiently to kill some trees. However, we suspect that drainage dynamics killed most trees indirectly by stressing them and causing them to be more susceptible to uprooting or breakage, thus creating light gaps.

Current habitat conditions within the Mingo Swamp reflect (1) man-made alterations in drainage systems, (2) the extensive logging operations during the early 1900's, (3) agricultural development, and (4) fires. A major recent development is the increase in area of dead-tree and S/S habitats caused by an increased beaver population (Mingo National Wildlife Refuge, unpublished annual reports) and construction of roads and levees.

Upper Mississippi Alluvial Valley

The proportion of habitat types and tree species apparently differ among Upper, Middle, and Lower MAV regions. Lowland hardwoods in the Lower MAV are flooded longer and deeper than those in the Upper MAV (Clark and Benforado 1981). Consequently, southern habitats are dominated by more water-tolerant species such as baldcypress, water tupelo, red maple, pumpkin ash (*Fraxinus profunda*), and buttonbush (Conner and Day 1976). Habitats present in the Middle MAV rely extensively on backwater flooding, and drainage systems are deeper, wider, and more extensive than in the Upper MAV. Forest sites in the Middle MAV, such as those at White River National Wildlife Refuge (NWR) in east-central Arkansas, are dominated by overcup oak, hackberry (*Celtis occidentalis*), cottonwoods (*Populus* sp.),

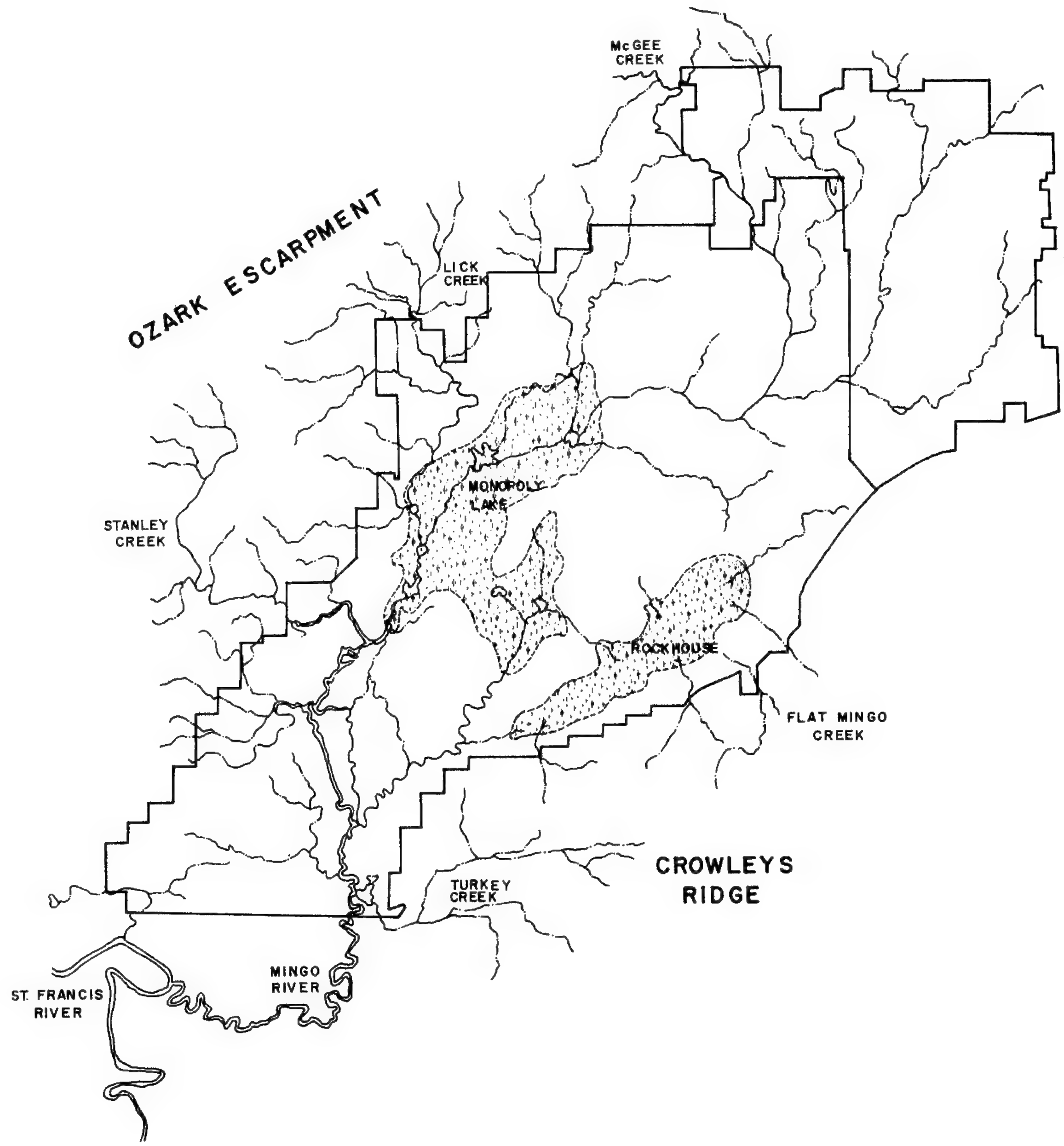


Fig. 12. Map of the Mingo Swamp in 1880 showing habitat types and drainage system locations.

red maple, water hickory (*Carya aquatica*), green ash (*Fraxinus pennsylvanica*), and American elm (*Ulmus americana*); there are smaller percentages of Nuttall oak (*Quercus nuttallii*), willow oak, black willow, sycamore (*Platanus occidentalis*), and sweetgum (Table 12). The Upper MAV has higher topography, drainage systems are shallower and less extensive, and periods of flooding are shorter and less frequent than in the Lower MAV. The predominant trees in the Upper MAV forests of the Mingo Swamp and Hatchie NWR in southwestern Tennessee are pin oak, Nuttall oak, willow oak, cherrybark oak, sweetgum, and hickories (Table 12).

Much of the Upper MAV was probably similar to the Mingo Swamp in historical times. An exception is the low basin in the Mingo Swamp (Monopoly Marsh), which contained a larger single expanse (622 ha) of baldcypress and water tupelo habitat than was found in most other Upper MAV locations. Numerous braided

Table 12. *Forest composition (percentage of total forested area) on Mingo, Hatchie, and White River National Wildlife Refuges.*

Forest type[a]	Mingo[b]	Hatchie[c]	White River[d]
Swamp chestnut-cherry bark oak	—	65.33	—
Overcup oak	11.12	4.34	50.33
Hackberry-elm-ash	—	—	16.60
Nuttall oak-willow oak-sweetgum	30.96	15.86	7.32
Red oak-hickory	25.76	—	1.88
Sycamore-American elm	—	9.65	0.22
Loblolly pine	—	—	0.01
Baldcypress	—	4.44	1.35
Oak-elm-ash	32.15	—	20.74
Cottonwood	—	—	0.48
Willow	—	—	1.06
Total hectares	5,033	3,734	40,779

[a] Society of American Foresters (1967) types.
[b] Data obtained in this study.
[c] Data obtained from timber cruises by Clyde Martin, Hatchie National Wildlife Refuge.
[d] Data obtained from timber cruises by Jim Johnson, White River National Wildlife Refuge.

streams drained and fed Upper MAV wetlands. Pin oak habitats apparently dominated forests in the Upper MAV and were interspersed with overcup oak habitats along drainages. Baldcypress and S/S habitats occurred along rivers, sloughs, natural ponds, and other depressions. Extensive areas of dead-tree or S/S habitats were probably uncommon. Likewise, few large natural ponds were present, with the exception of areas like Reelfoot Lake, Tennessee. Sloughs were probably numerous, but their size and depth were probably less than those in the Lower MAV.

On-site rainfall probably contributed a considerable part of the floodwater in Upper MAV wetlands. Backwater flooding was also important in the Upper MAV but probably less so than in the Lower MAV. All habitats in the MAV become flooded earlier, deeper, and more extensively in years of increased winter precipitation. When flooding occurred in the relatively flat topography of the Upper MAV, water probably spread shallowly over extensive areas rather than deeply over smaller areas. Wet winters seem important for replenishing nutrients and recycling both plant and animal communities, which spend more than half the time in dry habitats but require wet periods to germinate or reproduce. Conversely, dry winters allow plants and animals dependent on drought or drawdown to germinate or reproduce. These contrasting water regimes therefore facilitate the high diversity and productivity of Upper MAV forested habitats.

Management Implications

Maintaining lowland hardwood forests in the Mingo Swamp and throughout the Upper MAV with natural ecological functions seems dependent on maintaining near-natural water regimes. The effects of altered water regimes on plant and animal communities are partly known (Fredrickson 1979b; Cairns et al. 1981; Heitmeyer and Vohs 1981); certain of these suggestions merit emphasis, and others were developed from information gathered in this study.

1. Headwater and backwater flooding are integral parts of lowland hardwood wetlands. These annual and long-term water fluctuations are essential for maintaining functional plant and animal communities. Floodplain development should be appropriately conducted to ensure that this flooding continues. Placement of levees around existing blocks of forested habitats modifies flooding and consequently may have deleterious effects on plant and animal communities.

2. Water management should emulate near-natural seasonal and annual water regimes wherever possible. Static water management among years or creating more permanent water conditions may change habitat or tree species composition. At present, GTR water management in the Mingo Swamp has the apparent potential for enhancing the establishment and survival of such trees as overcup oak and red maple that are adapted to wetter sites, while developing conditions that curtail pin oak regeneration and survival. These changes in

forest composition seem related to yearly inundation from early fall to late spring. Changes in forest composition may be related to the rapid and deep early flooding in fall rather than to late flooding in spring. Lowland hardwoods appear to be adapted to regular flooding early in the growing season because natural flooding is more common in spring than late in the growing season. Modification of GTR's may alleviate some management problems by changing the duration, depth, and timing of flooding regimes among years to more closely emulate natural regimes.

3. Construction of roads, levees, and borrow areas should be restricted; those built should be designed to have minimal effect on natural hydrology, such as using large culverts and placing roads parallel to flows. The actual area required for construction of roads and levees destroys much of remaining habitats. Also, beavers use water control structures to impede waterflow, and their activity regularly extends permanent flooding into forested sites and causes conversion of live forest into dead-tree habitats. The combination of direct loss of habitat area from construction and habitat changes associated with beaver activity have the potential of influencing the value and condition of large areas of remaining forested habitats in the MAV. This potential for loss and damage points to the importance of controlling beaver populations in the Mingo Swamp as well as in other managed lowland hardwood habitats.

4. Efforts to preserve remaining lowland hardwood wetlands throughout the Upper MAV should be continued and accelerated. Because destruction and modification of forested wetlands have been more extensive in the northern than in more southern sections of the MAV, special consideration should be given to purchase and proper development of remaining forested sites. At present, the red oaks found at higher elevations where flooding is infrequent and shallow represent the habitat type in shortest supply in the Upper MAV. Stream channelization, construction of reservoirs and flood control structures, drainage of wetlands, and clearing of forests should be controlled to ensure that forests are not degraded further or lost. Mitigating losses of lowland hardwood wetlands in the Upper MAV is difficult because forest habitats cannot be fully replaced by other wetland communities. Although the reforestation of open habitats, such as marginal agricultural lands, requires a lengthy period before the structure and function of a forested system returns, this approach may play an important role in the long-term management potential of the Upper MAV.

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Appendix. Acronyms for Habitats Discussed in the Text.

Acronym	Meaning
MAV	Mississippi Alluvial Valley
MNWR	Mingo National Wildlife Refuge
DCWMA	Duck Creek Wildlife Management Area
S/S	Scrub/shrub
GTR	Green-tree reservoir
DN	Dead tree-new
DO	Dead tree-old
D	Ditch
R	River
OM	Open marsh
OW	Open water
ON	Overcup oak
OG	Overcup oak—green-tree reservoir
PL	Pin oak-low
PH	Pin oak-high
PG	Pin oak-high—green-tree reservoir
PHN	Pin oak/hickory
PHG	Pin oak/hickory—green-tree reservoir

Heitmeyer, Mickey E., Leigh H. Fredrickson, and Gary F. Krause. 1989. **Water and Habitat Dynamics of the Mingo Swamp in Southeastern Missouri.** U.S. Fish Wildl. Serv., *Fish Wildl. Res.* 6. 26 pp.

The present report describes lowland hardwood distribution and water relations in the Mingo Swamp in southeastern Missouri in 1981–83. These relations are examined in light of past and present management activities within the Mingo Swamp to provide a historical perspective on lowland hardwood wetland communities in the Upper Mississippi Alluvial Valley. Management suggestions include emulation of natural water regimes; restriction of road, levee, and borrow area construction; control of beaver populations; and continued protection of existing lowland hardwood forests in the Upper Mississippi Alluvial Valley.

Key words: Basin, wetland, habitat, forest, swamp, management, waterfowl, water.

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The following is a list of recent *Fish and Wildlife Research* publications.

1. Life History and Status of the Endangered Cui-ui of Pyramid Lake, Nevada, by G. Gary Scoppettone, Mark Coleman, and Gary A. Wedemeyer. 1986. 23 pp.
2. Spread, Impact, and Control of Purple Loosestrife (*Lythrum salicaria*) in North American Wetlands, by Daniel Q. Thompson, Ronald L. Stuckey, and Edith B. Thompson. 1987. 55 pp.
3. Taxonomy, Life History, and Ecology of a Mountain Mahogany Defoliator, *Stamnodes animata* (Pearsall), in Nevada, by Malcolm M. Furniss, Douglas C. Ferguson, Kenneth W. Voget, J. Wayne Burkhardt, Arthur R. Tiedemann, and John L. Oldemeyer. 1988. 26 pp.
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